1 THE MILITARY OPERATIONAL ENVIRONMENT

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Helmet- (and head-) mounted displays (HMDs) are but one of an array of technologies proliferating on the modern battlefield, now referred to as the "battlespace," thereby recognizing the true x, y, z three-dimensional (3-D) nature of today's military engagements. Some would argue that the battlespace has become multi-front and very fluid in nature and should be thought of as four-dimensional, adding time as an additional dimension.

The intent of these new technologies, especially HMDs, is to increase individual and unit performance to ensure mission success when operating in such complex scenarios. Advances in technology have successfully decreased the physical demands of many occupations but at the expense of increasing the mental or cognitive demands (Cheung, Westwood, and Knox, in press). Paradoxically, this increase in cognitive demand is paralleled and exacerbated by an increase in the availability of information needed to be processed in today's military setting.

In today's battlespace, information is considered as important as any weapon system. More and more, HMDs are becoming the mode of choice for presenting this information. HMDs provide Warfighters[1] with the capability of head-up presentation of the vast amount of tactical and strategic information becoming increasingly available at the individual Warfighter level. While long a mainstay of the aviation community, HMDs are rapidly expanding across all military applications, being fielded by infantry, mechanized, aviation and shipboard Warfighters alike.

An HMD can be described as a compact optical projection system, mounted on or built into a helmet, and used to project a scene and/or data directly into the eye(s) of the user (Laurin Publishing, 2005). In many applications, it is also referred to as a visually coupled system (VCS). While a basic HMD design may only consist of an image source with display delivery optics (attached to a helmet or other head mount), the concept of a visually coupled display includes some mechanism for head/eye tracking. An example of an HMD is provided in Figure 1-1, which depicts the Integrated Helmet and Display Sighting System (IHADSS) HMD used on the U.S. Army's AH-64 Apache helicopter (see Chapter 3, *Introduction to Helmet-Mounted Displays*).

To recognize the advantages, limitations and constraints of HMDs and their associated technologies for the Warfighter, and ultimately their impact on perceptual and cognitive performance, it is necessary to understand the military environment and how this environment and the role of the Warfighter itself have changed over the past few decades, as well as how they will change in the coming decades.

This chapter will attempt to present the multiple roles the modern Warfighter plays and the complex circumstances he/she faces. The diversity of Warfighter demographics, missions, working environment, and the tremendous physical, physiological, and psychological factors that are encountered are introduced and briefly described and will be further explored in the chapters that follow.

Current and Changing Roles

Whether an infantryman, helicopter pilot, tank mechanic, computer specialist, photographer, or cook, each member of the U.S. military is, first and foremost, a Warfighter. Historically, the primary job of every Warfighter has been to fight and defeat the enemy. However, the ending of the Cold War, the ever-changing role of the U.S. in world affairs, and the aftermath of September 11, 2001, have each expanded and added to the duties, tasks, and functions of today's Warfighter.

[1] Warfighter is a term used to describe all military personnel trained to engage in combat operations.

Figure 1-1. A representative HMD, the Integrated Helmet and Display Sighting System (IHADSS), used on the U.S. Army's AH-64 Apache attack helicopter.

In addition to being a combatant, today's Warfighter is at times called upon to be a peacekeeper, counter-drug specialist, anti-terrorist operative, humanitarian assistant, and disaster relief worker (Murray, 2001). In addition to these expanding roles, the Warfighter has a specific occupational area of expertise (i.e., job classification). Within the Army, these are referred to as Military Occupational Specialties (MOSs). Examples are Combat Engineer, Radar Repairer, Artillery Mechanic, and Accounting Specialist. Each of these specialties requires a certain knowledge base and mastery of a set of occupational skills (U.S. Department of the Army, 1999). For virtually all MOSs, the Warfighter may be required to assume the role of teacher/trainer, passing on accumulated knowledge and skills to other Warfighters. The other military services employ similar nomenclatures.

Role as a peacekeeper

No role for the Warfighter appears more opposite to the primary role as combatant than the role of peacekeeper. The U.S. has invested significant military, political, and economic resources in conducting operations following worldwide conflicts and civil unrest (Dobbins et al., 2003). While this role often is thought of as a recent phenomenon, the U.S. military has embarked on a number of such missions, spanning over 60 years. From post WW-II stabilization and reconstruction in Germany and Japan; through Korea in 1950; in Bosnia and Herzegovina (Bosnia) in 1995; and to Afghanistan and Iraq in 2002, the U.S. military, in the most recent century, has spent more time in the role of peacekeeping than that of combatant (until the most recent engagements in Afghanistan and Iraq) (North Atlantic Treaty Organization, 2001).

However, it was not until President Clinton established the U.S. Army Peacekeeping Institute (PKI) in 1993 within the U.S. Army War College (USAWC), located in Carlisle, Pennsylvania, following the catastrophe in Somalia, which the U.S. military sought to study and understand how Warfighters performed when sent in to carry out non-combat operations. (In 2003, the U.S. Army PKI was transformed into the U.S. Army Peacekeeping and Stability Operations Institute [PKSOI].)

The peacekeeping role borders that of law enforcement in many of its tasks. As such, it abounds with applications for HMDs. HMDs can provide tactical information and communications and can enhance situation awareness.

Role as a counter-drugs enforcer

The use of the military to counter illicit drug trafficking has been in effect at least since the mid to late 1980s, operating under the authority of the Posse Comitatus Act (1981 amendment) (Ahart and Stiles, 1991; Cathcart, 1989; Dickens, 1989; Simpson 1992; U.S. Army War College, 1988; U.S. Congress, 1989). Such efforts have been focused within, but not limited to, the South and Central Americas. In addition, units of the National Guard have been conducting surveillance missions in Latin America since the early 1990s (Haskell, 2004). National Guard counter-drugs task forces, such as in the California and Tennessee National Guard, are comprised of members of both the Army and Air National Guard. These guardsmen conduct observation missions within the United States in remote, rural, and semi-rural areas for long periods of time and depend heavily on HMDs with integrated night vision sensors that allow effective nighttime operation.

The use of military troops in anti-drug operations has not been without criticism, with both military and civilian leaders expressing concern about blurring the distinction between military and police authority (Marshall, 1988; Murray, 2001). However, it is more than likely that this role for the military will increase, not decrease, in the future.

Role as an anti-terrorist operative

Since the attack on the World Trade Center, September 11, 2001, military operations, primarily in Afghanistan and Iraq, have greatly expanded the role of the Warfighter into the area of antiterrorism. Of all of the expanded roles discussed, that of antiterrorist operative is the closest to that of the Warfighter's fundamental role of combatant.

The pursuit of Al Qaeda and other terrorist networks by U.S. military forces is worldwide. In addition to the highly publicized search for terrorist cells and insurgent personnel in Afghanistan and Iraq, the U.S. military is establishing programs throughout the world for the purpose of training local troops in methods to prevent the emergence of Al Qaeda in poor, rural areas. In one such program, the Pentagon is planning to train thousands of African troops as battalions equipped for extended desert and border operations and to link the militaries of different countries with secure satellite communications. This initiative, with proposed funding of $500 million over seven years, encompasses the countries of Algeria, Chad, Mali, Mauritania, Niger, Senegal, Nigeria, Morocco, and Tunisia (Tyson, 2005). The Pentagon also is assigning more military officers to U.S. embassies around the world, thereby hoping to increase intelligence gathering capabilities.

Special Forces units, as well as other Army units, can employ HMDs in search-and-destroy surveillance and search-and-rescue operations. As in other applications, HMDs can present tactical information, provide for communications, and increase situation awareness.

Role as a humanitarian aid and disaster relief provider

The military has long been involved in providing humanitarian assistance, both at home and abroad. Such assistance ensures the delivery of life saving and life sustaining aid to civilian populations. Humanitarian operations encompass a wide-range of missions, including sea search and rescue; refugee assistance and disaster relief; and the provision of food, medical supplies, and services (Juda, 1993).

Recent worldwide disasters, such as the December 2004 earthquake and resulting tsunami in the Indian Ocean region, have brought to the forefront the role that the U.S. Warfighter plays as a provider of humanitarian aid. Approximately 13,000 U.S. Navy, Marine Corps, Army, Air Force, and Coast Guard personnel were involved in the relief efforts following this disaster. By January 2005, military relief operations had flown over 400 missions and delivered 316,664 pounds of water, 135,102 pounds of food, and 8,246 pounds of medical supplies (U.S. Department of State, 2005).

Within the U.S., there were massive efforts by both the Active military and National Guard in response to the 2005 hurricanes Katrina and Rita – massive humanitarian assistance logistics (food, water and medical supplies) as well as all the search and rescue via rotary wing platforms from the Army, Navy and Coast Guard. Over 70,000 Active-duty and National Guard personnel were deployed either on the ground, in the air, or aboard ships supporting relief operations. Twenty U.S. Navy ships, 346 helicopters, and 68 fixed-wing aircraft were deployed to the area (Hiatt 2006).

The U.S. military has had a continuous worldwide presence, from Afghanistan to Uzbekistan, in humanitarian endeavors. These Warfighters, turned humanitarians, have delivered food and clothing, rebuilt infrastructure (e.g., orphanages, schools, and bridges), donated money for supplies and equipment, and worked side-by-side with local civilians to rebuild communities devastated by war or natural disaster (Barnes, 1989; Covey, 1992; Foster, 1983; Harrison, 1992; Jones, 1991; Kelly, 1992; Miles, 1991; Nalepa, 1993; Shotwell, 1992; Stackpole et al., 1993; Sutton, 1992).

It may be in this humanitarian role that the application of HMDs seems most out of place. However, when delivering food or rebuilding a school, the military relies on organization, planning, and communicating. Presentation of information via HMDs can assist in the performance of these functions, both at the command and control level as well as in the field.

The Demands of Combat

In spite of these ever-expanding roles, the primary purpose of a Warfighter is to engage in combat. Combat is defined as an engagement fought between two military forces. However, when such engagements are considered in the most personal manner (e.g., hand-to-hand fighting), this description falls far short of truly defining the essence of combat. The so-called "rigors of combat" are broad in scope - being physical, mental, and psychological in nature. It has been well recognized that the added uncertainty and stress of combat have a major effect on both physical and cognitive performance (Lieberman et al., 2002; Nindl, 2002; U.S. Army Center for Health Promotion and Preventive Medicine, 2005).

The physical rigors of combat, which include physical exertion, endurance, and overcoming the effects of extreme temperature, fatigue, and dehydration, are intended to be mitigated by intense physical training. Some common demands that combat places on Warfighters include marching long distances bearing heavy loads and still being able to function effectively; moving quickly and evasively under fire; carrying wounded to safety; setting up heavy weaponry; handling large-caliber ammunition for extended periods; climbing walls, cliffs, and other high obstacles; operating in physically confined spaces; and performing field maintenance on aircraft or heavy equipment (United States Marine Corps, 1998).

Just as critical to combat readiness are the mental and emotional states of the Warfighter. The competitive and combative spirit of the Warfighter has a tremendous impact on mission performance. Natural physical fear directly leads to cognitive degradation as well as physical fatigue, and these effects must be lessened by instilling confidence in the Warfighter — confidence in his performance, his command structure, and his equipment. The modern Warfighter is the most technologically advanced in the history of warfare. To make the most of this technology, equipment provided to the Warfighter must be reliable and useful and must enhance, not degrade performance. Through design and training, the operation of equipment must be second nature. The equipment must become a natural extension of the Warfighter.

The conditions under which military missions are or will be conducted will continue to vary with respect to the physical environment, the number of tasks, and the task complexity (National Research Council, 1997). In all situations, the Warfighter must be able to move, communicate, engage the enemy, and survive. It is the purpose of systems such as HMDs to offer the possibility of increasing individual Warfighter and unit performance.

Uniqueness of the Tri-Service Military Communities

While certain similarities exist, each of the four branches of the military has a distinctive operational environment and role. This individuality is defined by distinctiveness in mission, personnel and vehicles, and operating environments.

The U.S. Air Force's mission statement is to fly and fight in "air and space." The main component of the Air Force's arsenal is fixed-wing aircraft. With over 7,000 aircraft in service (Figure 1-2), the Air Force provides six distinctive core capabilities:

- Air and space superiority
- Global attack
- Rapid global mobility
- Precision engagement
- Agile combat support
- Information superiority

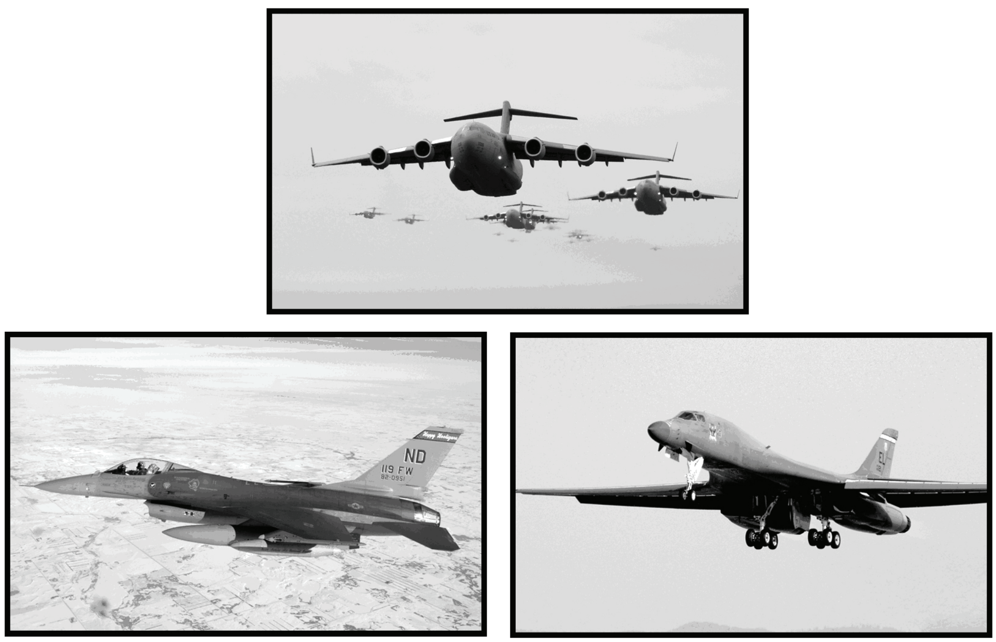

Figure 1-2. U.S. Air Force aircraft: C-17 Globemaster Tactical Transport (top center), F-16 Falcon Fighter (bottom left), and B-1B Lancer Bomber (bottom right). (Source: U.S. Combat Camera)

The latter capability emphasizes the ability of commanders and airmen to keep pace with information and to incorporate it into evolving plans of action.

The U.S. Navy operates in excess of 280 ships and 4,000 aircraft and is responsible for naval operations on the Earth's seas and oceans (Figure 1-3). As of January 2004, ship classes of the U.S. naval fleet included: Aircraft carriers, amphibious assault ships, amphibious transport docks, dock landing ships, submarines, cruisers, destroyers, frigates, and battleships. Naval aircraft include both fixed- and rotary-wing (helicopters) aircraft. These aircraft operate from the land as well as from ocean-going ships. Navy Warfighters have the most diverse operating environments, having to perform tasks on land, in the air, and on and beneath the water. The Navy also has expanded its harbor defense forces in response to the war on terrorism. The main components of Naval Harbor Defense include:

- Inshore Boat Units (IBUs)
- Mobile Inshore Undersea Warfare Units (MIUWUs)
- Special Boat Units (SBUs)

The Navy also has special warfare operatives, the "Navy Seals." Their primary purpose is to engage in "special activities other than war."

The U.S. Army is the branch of the U.S. armed forces that has primary responsibility for land-based military operations. The Army is highly focused on mobility and, therefore, maintains a diverse inventory of vehicles. Vehicle types include armored, transport and supply, and rotary-wing aircraft (Figure 1-4). Component-wise, the Army possesses the greatest proportion of combat personnel within the U.S. military forces. Within the Army, infantry Warfighters make up the largest contingent of combat personnel.

The U.S. Marine Corps serves as a versatile combat element and is adapted to a wide variety of combat operations. The Marine Corps possesses ground and air combat elements but relies upon the U.S. Navy to provide sea combat elements. A major mission of the Marine Corps is amphibious assault, the attack of an objective located on land by a force attacking from the sea. Landing craft are used to transport troops from ships to land. It is perhaps the most complex military maneuver in the history of warfare. Marines consistently use air, ground, and sea elements of combat together. Vehicles used by the Marines include fixed- (AV-8B Harrier), rotary-wing (AH-1Z Super Cobra and CH-53E Super Stallion), and hybrid (MV-22 Osprey) aircraft, plus assault amphibian vehicles (AAVP7A1) (Figure 1-5). Marines sometimes are employed to enter and hold an area until a larger military force can be mobilized.

Warfighter Demographics

From a human factors engineering (HFE) perspective, it is important to have an understanding of the users of a technological system or device. Previously, when only physical attributes of the user were considered, user anthropometry was most important. In aircraft design, arm and leg reach, torso height, etc., have been and still are important parameters. During the introduction of HMDs, a number of head and facial anthropometry measures were added to the list (Rash, 2000). These include the bizygomatic breadth (the maximum horizontal breadth of the face, between the zygomatic arches), eye inset (the distance between the supraorbital notch [eyebrow] and the cornea of the eye), the disparity between the two eyes, etc.

Now, as we wish to bring to the forefront perceptual and cognitive issues, it is important to expand our knowledge of the user population. In this section, the demographics of the Army user community are explored as a subset of the military user population, with comparisons to the other U.S. military services where available.

After the fall of the former USSR and the end of the Cold War, both the Federal Government and the Army Leadership realized that the structure of the 1960s' Big Army, designed to fight a protracted land war based in Europe, was no longer required, and a major reduction in active-duty forces was undertaken. This downsizing, occurring over the years 1992-1999, is reflected in Figure 1-6, which depicts U.S. Department of Defense active-duty military personnel strength levels for fiscal years (FYs) 1950-2002 (U.S. Department of Defense, 2005).

Although the size of the active-duty component of the Army has decreased since the mid 1980s from around 775,000 to about 490,000 today (approximately a 35% decrease), the distribution of ranks (officers, warrants, and enlisted) has remained fairly stable. However, changes in gender and ethnicity distributions have occurred.

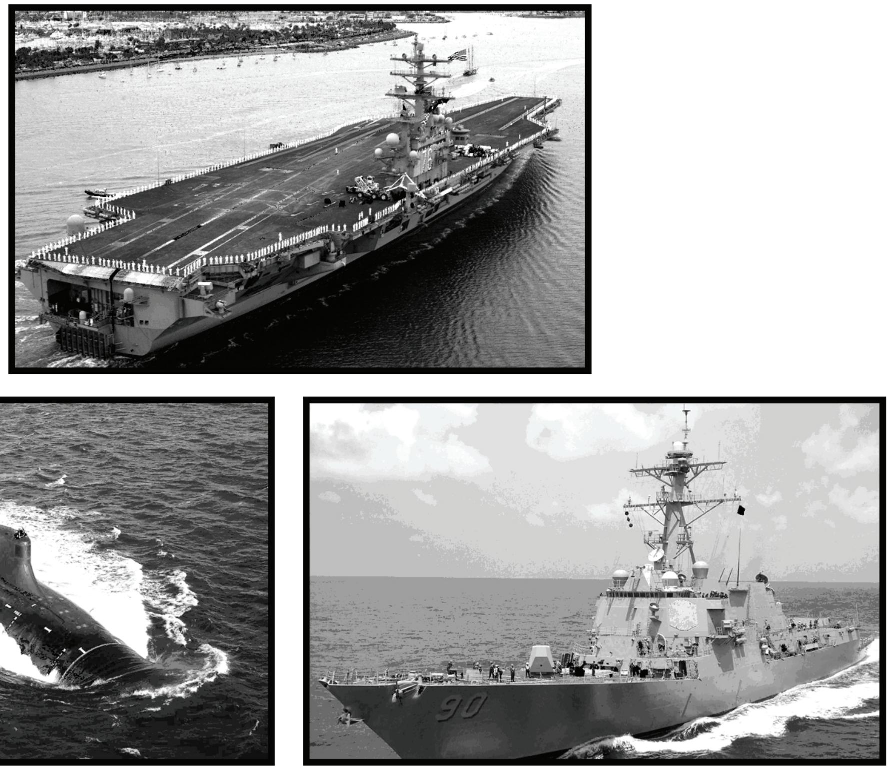

Figure 1-3. U.S. Navy vehicles: CVN-76 Ronald Reagan Aircraft Carrier (top center), SSN-23 Jimmy Carter Submarine (bottom left), and DD-356 Destroyer (bottom right). (Source: U.S. Combat Camera)

Figure 1-4. U.S. Army vehicles: AH-64D Apache Attack Helicopter (top center), M1A1 Abrams Main Battle Tank (bottom left), and M2 Bradley Infantry Fighting Vehicle (bottom right). (U.S. Combat Camera)

Figure 1-5. U.S. Marine Corps vehicles: MV-22 Ospry (top center), CH-53E Super Stallion (bottom left), and AAVP7A1 Amphibious Assault Vehicle (bottom right). (Source: U.S. Combat Camera)

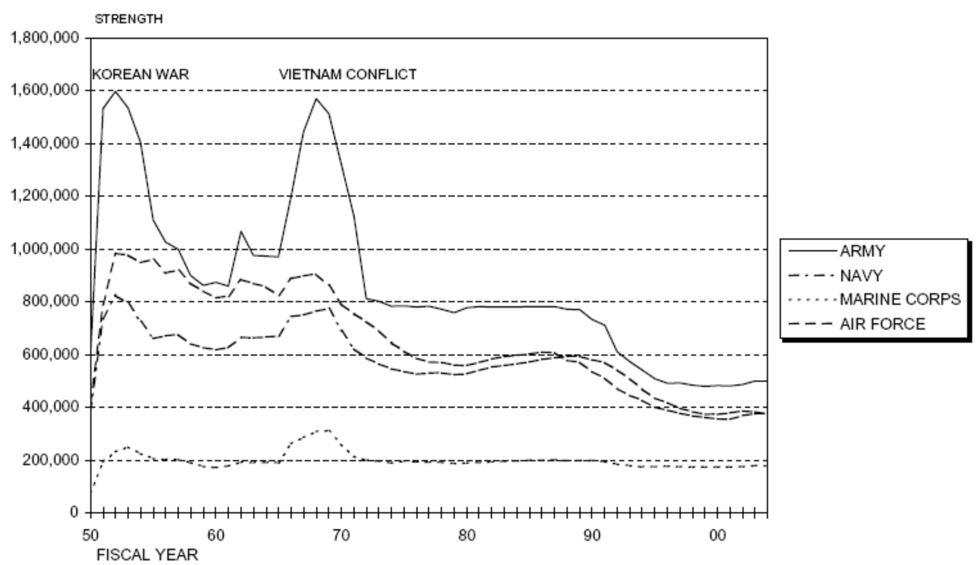

Figure 1-6. U.S. Department of Defense Active-Duty military personnel strength levels for fiscal years (FY) 1950-2002 (Source: Department of Defense, 2005).

Gender

It has been suggested that men and women have some basic behavioral differences, differences that may be based on dissimilarities between the male and female brain. As an example, it has been suggested that women are superior in certain language abilities, while men are superior in certain spatial abilities. Studies have documented an "array of structural, chemical and functional variations" between the brains for the two genders (Cahill, 2005). These studies have, in turn, highlighted gender differences, or biases, in cognition and behavior. Areas in which these differences exist include memory, vision, audition (hearing), and response to stress, all of which are factors that influence performance with HMDs. While within gender performance differences may exceed across gender differences, it still may be useful to define the gender breakdown within the potential user population.

The overall gender makeup of the active-duty Army has undergone significant changes since the end of the Cold War. While the total number of officer and enlisted women on active-duty has been rather constant, statistics show that the proportion of women has increased from approximately 10% to 15% over the period just preceding the end of the Cold War to 2003. This increase has been reflected in all ranks (Table 1-1) (U.S. Department of the Army, 2005).

Analogous data for the ten-year period only from 1993-2003 also show increases in the proportion of women from approximately 5% to 7% for the U.S. Marine Corps, from 16% to 20% for the U.S. Air Force, and from 12% to 15% for the U.S. Navy.

Table 1-1.
Proportion of U.S. Army active-duty women (1983-2003).
(U.S. Department of the Army, 2005).

Females Active Army	1983 (75,548)	1993 (70,797)	2003 (74,907)
TOTAL	**9.8%**	**12.5%**	**15.2%**
Officers	10.2%	14.2%	16.4%
Enlisted	9.9%	12.4%	15.2%
Warrants	1.3%	3.8%	7.1%

Race/Ethnicity

As with gender, there is reason to suspect that cognitive performance may differ with ethnicity. Such differences may have social, cultural, and economic causes (Rushton and Jensen, 2005). Therefore, as with gender, it may be useful to define the ethnic breakdown within the potential user population.

Over the same period considered for gender makeup, there has been a gradual shift in the racial/ethnic makeup of the active-duty military. For the Army, there has been a decreasing trend in the proportion of White and Black Warfighters over the period FY83-03; in contrast, there has been an increasing trend for Hispanic and Asian Warfighters over the same period (Table 1-2).

Within the U.S. Air Force, the proportion of Black Warfighters has been rather constant at approximately 15%, while the Hispanic proportion has increased only slightly from approximately 3% to 6%. For the U.S. Navy, both the Black and Hispanic Warfighter proportions have increased, from approximately 16% to 19% and from 7% to 9%, respectively. For the U.S. Marine Corps, Black Warfighter proportions have decreased from 17% to 13%, while Hispanic proportions have increased from 8% to 13%.

Table 1-2.
Ethnicity proportions of U.S. Army active-duty Warfighters (FY83-03).
(U.S. Department of the Army, 2005).

	FY83	FY93	FY03
White	64.0%	62.4%	59.3%
Black	28.3%	27.6%	24.0%
Hispanic	3.8%	4.7%	9.9%
Asian	1.3%	2.0%	3.5%
Other	2.6%	3.3%	3.3%

Education level

The modern Warfighter, by general standards, is well educated (Table 1-3). Almost 98% are high school graduates, and at least 96% of each of the U.S. military service's commissioned officers have earned college degrees (U.S. Department of Defense, 2004). For enlistment purposes, the military breaks education into three overall categories: Tier 1, Tier 2, and Tier 3. Tier 1 includes high school graduates or equivalent. Tier 2, known as Alternative Credential Holders, must achieve a minimum set score on Armed Forces Qualification Test (AFQT). The final tier (Tier 3) includes non-high school graduates, i.e., individuals who are not attending high school and are neither high school graduates nor alternative credential holders. However, the military services rarely accept a Tier 3 candidate for enlistment.

Table 1-3.
Educational level of U.S. active-duty military personnel.
(U.S. Department of Defense, 2004)

Education	U.S. Army	U.S. Navy	U.S. Marine Corps	U.S. Air Force
	Commissioned Officers			
College graduate[2]	98.7%	96.0%	97.2%	97.3%
High school graduate	100.0%	99.5%	97.9%	97.6%
	Warrant Officer			
College graduate[2]	31.5%	23.1%	14.4%	----
High school graduate	100.0%	100.0%	100.0%	----
	Enlisted			
College graduate[2]	5.3%	2.8%	1.3%	5.0%
High school graduate	98.5%	98.2%	99.2%	99.9%

While no direct correlation between education and cognitive skills is claimed, a higher level of education is considered to be an attribute that is advantageous in the use of technically complex systems.

[2] A 4 -year degree.

Age

The age of active-duty personnel can range from 17 [3] to 60. An age distribution based on 2004 data is provided, by gender, in Table 1.4. There is a relatively high correlation between the male and female distributions. The median age (based on reported data only) is 26 and 25, for males and females, respectively.

The U.S. military is relatively young. Approximately 47% of female and 41% of male active-duty personnel is under 25 years of age. Age has been shown to be a factor in cognitive performance in complex and simultaneous task environments. Becker and Milke (1998) cite that for the air traffic control occupation, where the ability to handle simultaneous visual and auditory input is critical to success, there is a strong positive relationship between age and job performance.

Table 1-4.
Age distribution of U.S. active-duty military personnel.
(Expressed in percent)
(U.S. Department of Defense, 2004)

Age/ Gender	19 or under[3]	20-24	25-29	30-34	35-39	40-44	45-49	50+
Female	8.96	37.74	21.70	12.27	9.45	5.66	2.36	0.94
Male	7.74	33.28	20.35	14.33	12.43	7.58	2.47	0.82

Note: 0.99% male and 0.94% female not reported.

Service components

All of the demographic statistics presented have been for active-duty personnel. However, in addition to the Active component of the military branches, there also is the Reserve component. The U.S. Army also has the National Guard component; the U.S. Air Force has the Air National Guard. For the Army, the total Army personnel strength at the end of FY04 was 1,041,340, with the active component (494,291) representing 47%, the reserve component (204,131) representing 20%, and the National Guard component (342,918) representing 33%. In peacetime, Reserve and National Guard personnel are generally confined to training operations. However, with Operation Enduring Freedom and Operation Iraqi Freedom, the Department of Defense has been relying heavily on the fielding of these components in combat operations. Demographic statistics for these components, for all military branches, are prepared annually by the Department of Defense's Washington Headquarters Services, Information Technology Management Directorate, Arlington, Virginia, and can be accessed via their website, http://www.dior.whs.mil/

Army Transformation Plan

As the U.S. military moves into the 21st century, it is adopting a new vision and a new model for its structure and operation. The form of warfare envisioned during the Cold War and the type of Armed Forces previously built to fight that war have been determined to be outdated, cost prohibitive, and ineffective. Today's and tomorrow's Armed Forces must be leaner and more responsive. A major principle of the plan to achieve this "transformation" is to depend more heavily on technology as a "force multiplier." HMDs are one of the many technologies being employed to achieve this goal.

Since the Army represents a major portion of the U.S. military personnel (approximately 35%, compared to 26% each for the Navy and the Air Force, and 12% for the Marine Corps), it may be instructive to look at the

[3] Age of 17 is the youngest enlistment age (with parental consent).

Army's ongoing program to restructure itself into a leaner, more technology-based organization. This restructuring is currently referred to as the "Army Transformation Plan."

For the latter half of the 20th century, the U.S. Army has been organized and equipped in preparation of fighting the large armies of the Soviet block. With the collapse of the Soviet empire and the end of the Cold War, the new challenges became multiple flashpoints scattered around the globe, e.g., Haiti, Somalia, Bosnia, Kosovo (Steele, 2001). To meet the changing demands on the future Warfighter, the Army is redefining itself via a transformation process that will bridge two decades.

The basic tenets of the transformation, while subject to modification, include (Murray, 2001; Steele, 2001):

- The future Army must become more responsive.
- A deployment capability plan must be able to put a combat-ready brigade anywhere in the world within 96 hours, a full division within 120 hours, and five divisions within 30 days.
- Equipment designated for the new Army will have increased capabilities and do much of the routine processing of data.
- The planned transformation must produce an Army that is more strategically, operationally, and tactilely mobile than current forces.

The Army Transformation plan provides for three forces: the Legacy force, the Interim force, and the Future force (formerly Objective force) (Murray, 2001). These three forces follow separate paths during the first decade of the transformation, finally merging into the new Army sometime near 2020 (Figure 1-7). The Legacy force consists of the Army's current heavy and light forces, e.g., the M1 Abrams tanks and the M2/M3 Bradley fighting vehicles. The Interim force improves on the capability of the Legacy force. It will consist of re-equipped heavy and light brigades that will be capable of faster deployment. These new units will be referred to as the Interim Brigade Combat Teams. The Future force will be the culmination of two decades of research and development. This force will possess a greater responsiveness, deployability, agility, and versatility than the current force.

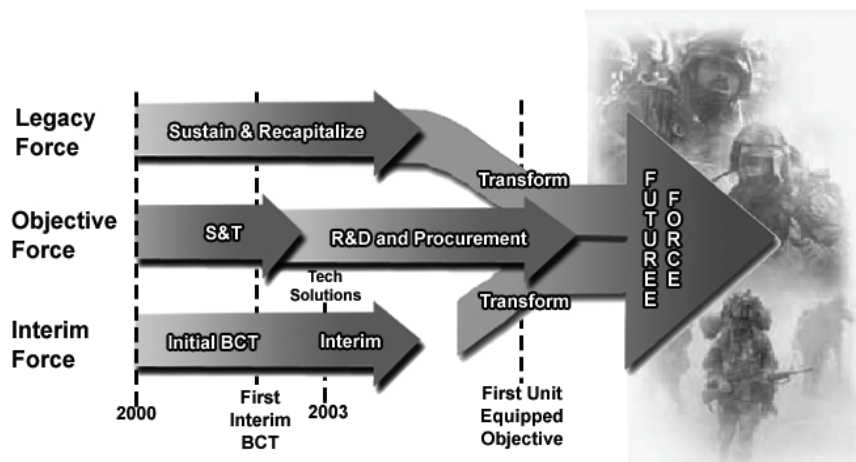

Figure 1-7. The Army Transformation Campaign Plan (Adapted from Murray, 2001).

The Future Force concept exploits the vast opportunities made possible by the expected capacity to quickly collect, organize, and distribute battlespace information. Data from multiple sources, e.g., sensors and databases, will be available to the Warfighter. It is critical that technologies such as HMDs employed in systems inherent to the Future Force concept be Warfighter-centered so as to enhance cognitive functions. Science and technology (S&T) and research and development (R&D) will play major roles in the Future Force design.

Under the Army's Future Force concept, the Warfighter is referred to as the Future Force Warrior (FFW). The concept seeks to create a lightweight, overwhelmingly lethal, fully integrated individual combat system, including weapon, head-to-toe individual protection, networked communications, Warfighter-worn power sources, and enhanced human performance, demonstrating "optimized cognitive and physical fightability." The Warfighter will become a "system-of-systems." One integral system is a "head-borne vision enhancement" system (an HMD) that provides fused I^2/IR sensor imagery (U.S. Army Natick Soldier Center, 2004).

An important challenge for the military planners of the Interim and Future Forces will be the development of Warfighter training that emphasizes intellectual development, flexibility, pragmatism, and cognitive decision making. Decision making is an inseparable component of all cognitive activities. The 21st century Warfighter must be able to select the critical information from a host of data made available by new technology and must be technically competent in the operation of such technology, such as the HMD, which will play a major role in the presentation of the information (Murray, 2001).

Battlespace Information, Information Superiority, and Network Centric Warfare (NCW)

With the explosion of imaging sensor technologies, the arrival of unmanned aerial systems (UASs) in the battlespace, the development of miniature, low-power displays, and the ability to link high-quality data and images via high-speed communication systems, the battlespace is saturated with information, with virtually all of it being made available to the individual Warfighter. It is crucial that Warfighters and their commanders receive this continual flow of information in order to achieve information superiority (Matson and DeLoach, 2003).

Information superiority in the battlespace means having an advantage in acquiring, processing, and distributing information on the status and location of your Warfighters and the enemy's Warfighters. This superiority also results in an uninterrupted flow of battle information while denying an enemy's ability to have the same information (Cohen, 1999).

Garstka (2000) suggests that to understand how information impacts our ability to conduct military operations it is necessary to consider three domains—the physical domain, the information domain, and the cognitive domain (Figure 1-8). The physical domain consists of the material battlespace where the intent is to exert influence or control in the situation. It encompasses the environments of land, sea, air, and space and is where the physical platforms and the communications networks that connect them are located. This is where the information resides; it is where information is created, shaped, and shared. It is the domain that makes possible the distribution of information among Warfighters.

The information domain is the domain where the data exists. It is where the data are created, manipulated, and shared. It is the domain that facilitates the distribution of information between Warfighters. It is the domain where the command and control of modern military forces is exercised, where commander's intent resides. In the key battle for information superiority, the information domain is "ground zero." Information Superiority is a condition in the information domain, a condition that is created when one adversary is able to establish the superior information state (Garstka, 2000).

The third domain is the cognitive domain, which is in the brain of the Warfighter. This is where perceptions, awareness, understanding, beliefs, and values reside and where decisions are made. Most importantly, this is the domain where most battles and wars are won and lost. The cognitive domain is where concepts of leadership, morale, unit cohesion, level of training and experience, situational awareness, and public opinion are found. This is the domain where an understanding of the battle plan, doctrine, tactics, techniques, and procedures influences decision-making (Garstka, 2000).

All of the contents of the cognitive domain are filtered by human perception. This filtering is defined by the Warfighter's individual worldview, the body of personal knowledge the Warfighter brings to the situation, experience, training, values, and individual capabilities (e.g., intelligence, personal style, perceptual capabilities, and cultural background). While there is one reality (physical domain), which is transformed into selective data, information, and knowledge by the various sensor and imaging systems in the battlespace, each Warfighter has his/her own perception of reality. The military, through training and shared experiences, strives to mold these individual perceptions and resulting cognitive behavior into a similar collective perception of reality (Garstka, 2000).

An important aspect of this reality is situation awareness. Situation awareness refers to the Warfighter having a global awareness of the tactical situation and of his/her status within the situation. The components of the situation include mission purpose, mission constraints, environmental factors, available resources, and interaction with other Warfighters and Warfighter elements. Alberts et al. (2001) discuss situation awareness within the context of the cognitive domain. Maintaining situation awareness in the presence of the high information flow in the modern battlespace requires considerable cognitive function. If cognitive function is compromised due to any of a host of factors, situation awareness also becomes compromised. Further, this awareness must be shared and yet must avoid both cognitive illusions and "groupthink."[4]

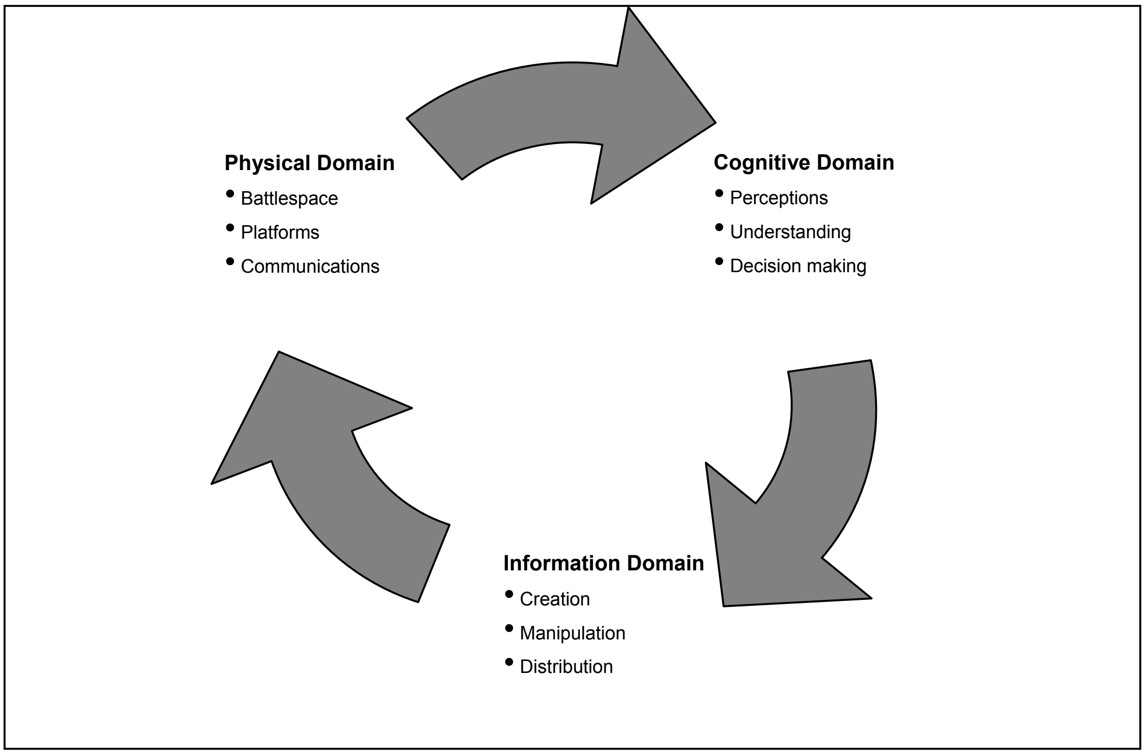

Figure 1-8. The three domains that aid in the understanding of how information impacts the conduct of military operations. (Suggested by Garstka, 2000)

The relatively modern concept of having the ability for geographically dispersed Warfighter forces (individuals, teams, and higher order structured units) to create and maintain a high level of shared battlespace awareness that can be exploited via self-synchronization and other operations to achieve strategic success is known as Network Centric Warfare (NCW) (Alberts et al., 1999). NCW is about human and organizational behavior in the battlespace. It mandates adopting a new way of thinking—network-centric thinking—and applying it to military

[4] The term "groupthink" was suggested by the psychologist Irving Janis in 1972 to describe a process by which a group can make poor decisions that result from each member of the group attempting to conform to what they believe to be the group consensus.

operations. NCW focuses on the combat power that can be generated from the effective linking or networking of the warfighting elements, converting the position of information superiority into military action.

The Physical Environment

Most professions and occupations have a single working environment whose characteristics define a set of typical surround conditions within which the worker performs tasks or duties. This is not the case for the Warfighter. The Warfighter's physical environment runs the gamut from benign to severe. Physical factors that could affect both human and equipment performance must therefore be taken in consideration include operation in confined spaces, at high altitudes, in reduced illumination levels, in adverse weather conditions (e.g., rain, sleet, snow, fog, etc.), in smoke and other battlespace obscurants, in regions of extreme heat or cold, etc.

Until the recent trend to shift to performance specifications and to adopt more off-the-shelf technology, the military was well-known for establishing rigid specifications. Referred to as military specifications (MIL-SPECs) and military standards (MIL-STDs), these specifications precisely defined the operational environmental requirements of newly developed devices and systems. These publications are still widely used and routinely referenced in many performance specification documents. These specifications and standards typically address such environmental factors as temperature, altitude, solar radiation, humidity, rain, sand, dust, vibration, shock, salt, fog, fungus, etc.

The only dedicated military specification or standard for HMDs is MIL-A-49425 (U.S. Department of Defense, 1989) for the Aviator's Night Vision Imaging System (ANVIS), an image intensifier (I^2) tube-based HMD. However, there are a number of such documents which are directly or indirectly applicable. These include, but are not limited to, MIL-STD-461E (Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference), MIL-STD-1295 (Human Factors Engineering Criteria for Design Criteria for Helicopter Cockpit Electro-Optical Displays Symbology) (U.S. Department of Defense, 1999), and MIL-STD-1472 (Human Engineering Design Criteria for Military Systems, Equipment and Facilities) (U.S. Department of Defense, 1981). The latter two examples are specifically cited for their guidance in addressing human factors issues. The U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL, also has published a performance-based design guide, *Helmet-Mounted Displays: Design Issues for Rotary-Wing Aircraft* (Rash, 2000).

However, while these specifications and standards have been very effective in ensuring that systems be designed to operate properly in harsh military environments, they do not guarantee that operational user performance in these environments will not be affected. For example, today's Warfighters deploy worldwide. They can be required to operate in regions of extreme heat or cold for long periods. Such temperature extremes can be encountered both in the outside, exposed environments, as well as in the inside, enclosed spaces of ships, tanks, aircraft, etc. Working temperatures in excess of 100°F (38°C) have been recorded in tank cabins and aircraft cockpits. Both heat and cold temperature extremes impact not just system performance but user performance as well. In such regions, the physiological conditions of heat and cold stress may be present. In extreme conditions, injuries of heat exhaustion or heat stroke and frostbite or hypothermia can result.

The physiological effects of heat stress can include fatigue, nausea, headache, and fainting. But, heat stress also can reduce mental performance. Even moderate heat environments take a toll on performance. Tasks that require attention to detail, concentration, and short-term memory will become more difficult. Heat stress slows reaction and decision time. Routine tasks are done more slowly. Vigilant task performance is degraded (U.S. Departments of the Army and Air Force, 2003). It has been suggested that impairment of cognitive performance by heat stress is a function of the resulting internal body temperature during exposure (Hancock, 1981).

An excellent summary list of guidelines for the impact on Warfighter performance is provided by Johnson and Kobrick (2001) and includes:

- Although not directly affected by heat, vision likely will be impaired by secondary factors such as sweat running into the eyes and moisture obscuring optics and lens surfaces.

- Visual distortions due to heat, such as mirages, optical illusions, shimmer and glare, can reduce spatial vision.
- Performance of some visual tasks, such as rifle aiming and distance judgment, can be degraded.
- Equipment controls can interfere with efficient manual operation when they become too hot to handle comfortably.
- Sweating can cause headgear and headphones to become unstable and slide on the head, compromising hearing, vision, and the performance of other tasks.
- Tasks requiring sustained attention, such as sentry duty, watch keeping, and instrument monitoring, will be aversely affected.
- Complex mental tasks, such as mathematical reasoning and decoding of messages, can deteriorate in heat above 90ºF (32ºC) after about 3 hours.
- Continuing heat exposure causes progressive motor instability, leading to impaired steadiness and manual dexterity.
- Target tracking, in which the Warfighter must judge differences in continuous target alignment, can degrade.
- Simple tasks are less affected by heat than are highly complex tasks. Moderately complex tasks tend to be the most resistant to heat effects because they tend to sustain attention while placing only moderate demands on the Warfighter's overall performance.
- Multiple tasks (i.e., two or more tasks being performed concurrently) are more affected by heat than any of the same tasks performed individually.
- Discomfort reactions are widely different among individuals, and heat acclimatization and experience greatly influence degrees of discomfort. High humidity in tandem with conditions of heat compound discomfort.
- Symptoms of heat illness seriously degrade Warfighter performance, and symptom intensity varies widely among individuals.

Cold stress can have equally degrading effects on performance. Physiological effects can include uncontrollable shivering, slow and irregular heartbeat, low blood pressure, fatigue and drowsiness, and pain in the extremities. Cognitive effects for cold stress have been much less investigated than effects for heat stress but include memory lapses and incoherence. In the battlespace, individuals working with computers or other skills requiring fine motor control and good decision-making skills have been shown to be especially vulnerable to the effects of even moderate cold stress (Pozos and Danzl, 2001).

A number of studies have documented decreases in visual vigilance task performance (Hoffman, 2001). However, substantial decrements are likely to be present only during rapid changes in core body temperature, such as with sudden water immersion.

While simple reaction time seems to be relatively unaffected, decrements in cognitive function due to cold increase with task complexity. To offset the effects of cold stress, it might be necessary to pre-divide complex tasks into multiple subtasks.

Additional Operational Factors

Physical factors of the environment are not the only ones that must be considered in the design, development, and fielding of a new device or system. A number of additional factors must be addressed to ensure that user performance with the device or system is optimized. Rash (2004) developed a list of adverse operational factors that should be considered for their possible impact on operational performance with advanced display concepts, to include HMDs. The list contains 19 generalized factors categorized as physical/environmental, mechanical, physiological, sensory, and psychological in nature (Table 1-5). This list of factors should not be considered exhaustive.

Within the mechanical category, the HMD may be worn in conjunction with corrective eyewear and/or some type of chemical, nuclear, biological (NBC) mask. Rash et al. (2002) states that limited mechanical clearance (referred to physical eye relief) between the optics of an HMD and add-on devices, such as corrective spectacles, oxygen masks, NBC masks, etc., can impact fit and the ability to achieve the full field-of-view of the HMD imagery.

Optical alignment problems that can affect targeting tasks and associated decisions can be introduced when the HMD is worn in combination with one or more of these devices. This effect arises from the induced prismatic deviation caused by the presence of multiple optical surfaces.

Table 1-5.
Adverse operational factors to be considered for impact on operational performance with advanced display concepts.

Category	**Factor**
Physical/Environmental	Temperature (Heat/Cold) Presence of obscurants (Smoke, fog, etc.) Precipitation Sun effects (Sunlight readability)
Mechanical	Interface with NBC and oxygen mask Eyewear (Glasses/Contacts) Vibration and shock
Physiological	Fatigue Hypoxia Sleep deprivation G-loading Existing medical conditions Physiological state (Electrolyte balance, hydration level, etc.) Use of prescribed drugs and over-the-counter (OTC) medications
Sensory	Glare Luminance transients (Flashblindness) No/Low illumination Noise (Impulse/Steady-state)
Psychological	Mental/Emotional state (Stress) Fear/Anxiety Workload

Mechanical factors

In aviation and ground vehicular applications, the HMD must be able to operate satisfactorily in the presence of vibration and mechanical shock (Rash, 2000). Helicopters and ground vehicles produce high levels of vibration. This vibration affects both the vehicle and the operator. Human response to this vibration has been a more difficult problem to understand and solve than that with the aircraft (Hart, 1988). The effects of vibration manifest themselves in retinal blur, which degrades visual performance, and in physiological effects, the resulting degradation of which is not fully understood (Biberman and Tsou, 1991). The problem of the presence of vibration is exacerbated by the fact that all vehicle types differ in their vibration frequencies and amplitudes. Achieving full field-of-view of HMD imagery depends on maintaining proper alignment of the HMD optics, which is a difficult task in the presence of vibration.

Physiological factors

Fatigue, hypoxia, G-loading, sleep deprivation, and the use of drugs/medications are physiological factors that will degrade performance. Fatigue, sleep deprivation, and disruption of circadian rhythm are natural consequences of today's military operational planning where rapid force deployment across multiple time zones is expected, often followed immediately by a high operational tempo. Besides high operational tempos, uncomfortable working and sleeping environments, sustained operations, and insufficient staffing make fatigue a growing concern (Caldwell and Caldwell, 2005). Loss of sleep degrades attention, cognitive speed and accuracy, working memory, reaction time, and overall behavioral capability, often without the sleep-deprived person being aware of the deficits (van Dongen and Dinges, 2000).

Primarily a high altitude aviation problem, hypoxia, a decrease in ambient oxygen level, has significant effects on cognitive function. In mild cases, hypoxia causes only inattentiveness, poor judgment, and reduced motor coordination. Severe cases result in a state of complete loss of awareness and unresponsiveness where brain stem reflexes, including pupillary response to light and breathing reflex, cease.

Hypoxia also can be an issue for mountain operations (Cymerman and Rock, 1994). Warfighters deployed to high mountain terrain can experience a number of effects in vision, cognitive function, psychomotor function, mood, and personality. These effects are directly related to altitude and are much more common over 10,000 feet (3,048 meters). Both cognitive and psychomotor performance degradation occurs at altitudes greater than 10,000 feet (3,048 meters). The effects are most noticeable at extreme altitudes (>18,000 feet [>5,486 meters]) where degradation in perception, memory, judgment, attention, and other mental activity can occur (Cymerman and Rock, 1994).

Another physiological factor, generally confined to the high-performance aviation community, is G-loading. Under G-loading, a pilot's body is subjected to forces many times that of normal gravity (G). A pilot in an aircraft experiencing 4-Gs will be subjected to a force four times that of the force due to gravity. An F-16 fighter jet can pull in excess of 9 Gs during maneuvers.

Without appropriate countermeasures (e.g., wearing of a G-suit, a specialized garment worn by pilots subject to high levels of acceleration in order to prevent loss of consciousness), the effects of excessive G-loading can range from grayout to blackout to loss of consciousness (Harvey, 2006). Grayout is a reduction in visual capacity (often reported as a graying of vision) due to diminished blood flow to the eyes. This can result in a loss of peripheral vision (i.e., tunnel vision) and a loss of color perception and scene contrast but no loss of consciousness. The pilot still has auditory, tactile, and cognitive functions. Full vision can be recovered in two to three seconds after removal of the G-loading. In blackout, the oxygen supply to the eyes' retinas is severely reduced. A complete loss of vision occurs but still no loss of consciousness. Again, the pilot still can hear, feel, and think. Recovery time is a matter of two to three seconds after removal of G-loading. Most severe is loss of consciousness. The subject can no longer hear, feel, or think. Recovery does not occur for 15 to 20 seconds after the G-loading is removed. The time required to return to consciousness may vary from 9 to 20 seconds, and the pilot does not regain full, normal function for several minutes (Beaudette, 1984).

A final physiological factor to be mentioned here is the possible influence of prescribed drugs or over-the-counter (OTC) medications, used either as temporary or long-term medical condition management or as an operational necessity (e.g., countermeasures for fatigue during critical sustained operations). In the aviation community, pilots are routinely grounded if a medical condition warrants the use of prescription drugs. One major future exception to this fact is when approved drugs are administered for operational reasons in extreme situations, e.g., as fatigue countermeasures. The Air Force and the Army have been researching this possibility

(Caldwell et al., 2002a; Caldwell and Brown, 2003). Analogous research has investigated the use of short-acting hypnotics to improve daytime sleep and nighttime performance due to night shift work (Caldwell et al., 2002b).

Even OTC medications that are generally considered harmless can affect performance, both physical and cognitive. Users frequently ignore the ever-present warning against the operation of equipment and machinery during use. Even cold and allergy medications labeled as “non-drowsy” still list sleepiness as a possible side effect.

Perhaps the most used drug in the world is caffeine, present in coffee, tea, and many cola drinks. These high-level caffeine beverages are consumed innocently in large doses over long time periods. Military lore touts the advantages of coffee and tea for keeping Warfighters awake and alert, both on and off the battlefield. Caffeine is a drug that stimulates the central nervous system. Caffeine works on the body by increasing the heart rate, digestive secretions, respiratory rate, metabolic rate, and urine output. Low doses (~ 3 cups of coffee per day) increase alertness, while also increasing urination frequency and stomach acid levels. Higher doses can produce headache, irritability, insomnia, diarrhea, depression, and hyperactivity. Performance enhancement and side effects vary greatly among individuals. Sudden termination of caffeine consumption can result in withdrawal symptoms such as headache, lethargy, difficulty in concentration, and mild nausea.

A 1993 cross-sectional survey of over 9000 Britons investigated the relationship of habitual coffee and tea consumption to cognitive performance (Jarvis, 1993). Subjects completed tests of simple reaction time, choice reaction time, incidental verbal memory, and visuo-spatial reasoning, in addition to providing self-reports of usual coffee and tea intake. The study concluded that overall caffeine consumption showed a dose-response relationship to improved cognitive performance for each cognitive test. Older subjects appeared to be more susceptible to the performance-improving effects of caffeine than were younger subjects.

Sensory factors

Warfighter performance also can be impacted by sensory-related factors, such as the presence of loud and/or constant noise, sudden transients in luminance, glare sources, and operation in periods of no or reduced illumination (which can include operating at night, in foul weather, in caves, and in darkened ship interiors).

Sound provides important, useful information to the Warfighter. It can denote the presence of the enemy, contain strategic or tactical communication, provide information about the status of the local environment or vehicle being used, etc. Sound that is considered non-useful or distracting is identified as noise. A formal definition of acoustical noise is random occurrences of energy spikes varying in both amplitude and frequency (formally having a flat power spectrum across a significant portion of the human auditory response spectrum). Noise is generally characterized as either continuous (steady state) or impulse. As the noise level increases, it can progress from simply being annoying to being painful and damaging. At any level, noise can degrade communication, thereby increasing the potential for error.

Steady state noise technically is defined as lasting one second or longer but more commonly is continuous over the time period of concern. Common examples of steady state noise include road navigation noise, engine and generator noise, aerodynamic noise associated with wind or water rushing over vehicle exteriors, and electronic static. Steady state noise can mask important sounds that contain information. While low-level steady state noise exposure (less than 85 decibels) has not been thought to create adverse health effects, recent troop deployments to Bosnia and Kosovo have shown that low-level noise near military airports significantly impacted individual sleep habits and other noise-sensitive tasks (Luz et al., 2004).

Studies investigating the effects of steady-state noise on cognitive function have shown degradation in reading acquisition, time reaction to perceptual stimuli, attention, both intentional and incidental memory, and complex task performance (Dudek at al., 1991; Lercher, Evans, and Meis, 2003). Noise interferes in complex task performance, modifies social behavior, and causes annoyance. Noise exposure also has been shown to have adverse health effects. Studies of occupational and environmental noise exposure suggest an association with hypertension, whereas community studies show only weak relationships between noise and cardiovascular disease (Stansfeld and Matheson, 2003).

Impulse noise is defined as very intense sounds of short duration, abrupt onset and decay, and high intensity. Impulse noise describes the kinds of sound made by explosions, aircraft breaking the sound barrier, and the discharge of firearms. Exposure to impulse noise may result in temporary and permanent shifts in the threshold of hearing (Hodge and Price, 1978). Intermittent impulse noises will mask speech in varying degrees. Impulse noise in isolated one-second bursts is unlikely to disrupt much speech communication due to the redundancy of speech. However, as the frequency and duration of the noise bursts increase, so does the masking effect (U.S. Environmental Protection Agency, 1973).

Many sources of potentially distracting and damaging noise exist in the military environment, including weapons systems, wheeled and tracked vehicles, fixed- and rotary-wing aircraft, ships, and communications devices. Warfighters encounter noise through training, standard military operations, and combat. Warfighters also may be exposed to noise through activities that are present but not unique to military service, including engineering, industrial, construction, and maintenance tasks (Durch and Humes, 2006).

Studies have determined that individuals exposed to steady state sound levels of 85 decibels (A) (dBA) for an 8-hour period or longer are in danger of losing their hearing. Likewise, individuals exposed to impulse noise of 140 decibels (P) (dBP) or greater also are in danger of hearing loss (U.S. Army Center for Health Promotion and Preventive Medicine, 2006). Studies have shown that many Warfighters operate with hearing decrements (Humes et al., 2005; Shaw and Trost, 2005).

Military vehicles generally are not sound insulated, and weapons, by virtue of their operation, are sources of higher noise levels. Typical noise environments associated with the operation of military vehicles and weapons include the Army's M2 Bradley Fighting Vehicle (74-95 dBA at idle), the Army's UH-60A Black Hawk helicopter (106 dBA in cockpit), the Air Force's F-16 fighter (103 dBA in cockpit), and the Navy's coastal patrol craft (112 dBA in engine room).

A new source of impulse noise has arisen in the U.S. Army as the inadvertent result of an effort to introduce airbags into Army helicopters to reduce impact injuries during crashes (Ahroon et al., 2002). Deployment tests of airbag systems in the Army's UH-60 Black Hawk helicopter measured impulse noise levels from 144.8 to 162.4 dBP sound pressure level. Similarly, in Navy and Air Force aircraft, ejection seat operation can generate impulse noise levels in excess of 165 dBP (Naval Air Test Center, 1981). Of course, in both environments, pilots wear protective helmets with integrated noise attenuation, as well as supplemental noise protection in the form of earplugs.

No/Low illumination

Modern military operations are all-weather, day and night in nature. Combat operations no longer are confined to daytime or illuminated battlefields. Modern sensors expand the Warfighter's capability to fight in rain, fog, and even total darkness. Using microwave, radar, I^2, infrared (IR), and other technology-based imaging sensors, the "seeing" range of the human eye is extended into the darkest of nights and the gloomiest of weathers. However, this capability does not come without cost. Warfighters are expected to view, interpret, and make decisions on these "altered" representations of the outside world. Targets and backgrounds in these altered images are not presented to the eye and brain in the same mode (i.e., with the same spatial content) as when viewed by the natural unaided eye. Time-tested perceptions of objects are no longer fully usable when viewing images acquired from spectral ranges that extend beyond and may not include the normal visual range. As an illustration, Figure 1-9 depicts three presentations of the same scene, one as acquired by the unaided human eye, one as an IR sensor, and one as a radio frequency sensor (Wang, Wang and Peng, 2003).

Psychological Factors

The final category of adverse operational factors, one that is too frequently overlooked, is cognitive factors. Workload and the mental/emotional state of the user (defined by such conditions as stress level, presence of fear and anxiety, etc.) are factors that affect the user's level of attention to and retention of information presented via the HMD.

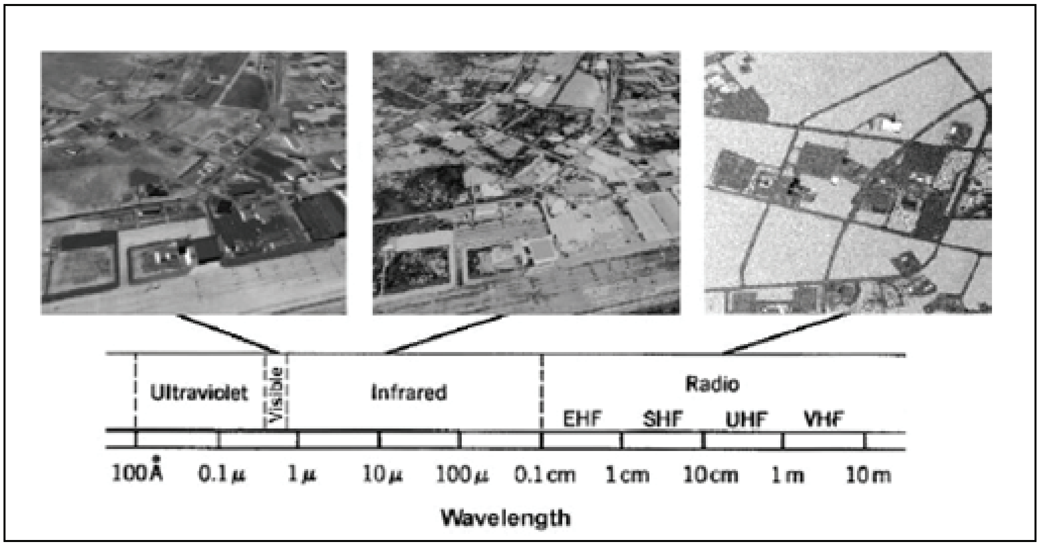

Figure 1-9. Three views of a scene as acquired by the unaided human eye (left), an IR sensor (center), and a radio frequency sensor (right) (Wang et al., 2003).

An undeniable consequence of the use of HMDs in NCW is increased workload. Workload can be defined as the combination of task demands and human response to these demands (Mouloua et al., 2001). In general, workload can be categorized as physical or cognitive. From the perspective of NCW and HMDs, the workload is cognitive in nature. Cognitive workload (or cognitive demand) is not well studied nor well understood, especially in scenarios where both physical and cognitive workload coexist or where multiple, simultaneous cognitive tasks are present (National Research Council, 1997). In addition, effects of and response to workload level differ for excessive and low workload scenarios.

In the benign environment of the development and testing laboratory, devices and systems based on advanced technologies may demonstrate superior performance; in a training environment, performance is often reduced. However, it is only when actual combat conditions and stressors are present that a true evaluation of system and user performance can be realized.

Combat stressors can be both physical and psychological. Physical stressors have a direct effect on the body. They may be both external and internal in origin. External physical stressors usually reflect the external environmental conditions, e.g. heat, cold, noise, and have been introduced previously in this chapter. Internal physical (or physiological) stressors, which include fatigue, hypoxia, sleep deprivation, G-loading, existing medical conditions, physiological state, and the use of prescribed drugs and OTC medications, also have been discussed in a cursory manner in this chapter and will be expanded upon in Chapter 16, *Performance Effects Due to Adverse Operational Factors*.

All of these physical (external and internal) stressors also place demand on the human cognitive and emotional systems, manifesting themselves as slow thought processing, memory lapses, anger, and/or fear (U.S. Army Center for Health Promotion and Preventive Medicine, 2005). Actual individual performance, with or without the use of advanced technology devices (e.g., imaging sensors and HMDs), is determined by the human response to these stressors. Humans respond with either physiological and mental reactions or reflexes designed to counteract these stressors. Responses may include decreased blood flow to the brain, muscles, and the heart; increased sweating; adrenaline release for energy and alertness; and muscle tension. These responses are intended to keep individuals within the range of physiological, emotional, and cognitive performance levels that optimize performance for survival.

The Warfighter's specific emotional and psychological reactions to combat have been referred to as "battle fatigue." Battle fatigue is described as a temporary response to the stress of combat capable of reducing combat performance by 10 to 50 percent. It is considered an inevitable consequence of military conflict (Hazen and Llewellyn, 1991). In modern times, this condition has been recognized as a distinct diagnostic phenomenon, referred to as Posttraumatic Stress Disorder (PTSD) (American Psychiatric Association, 1980). It was categorized as an anxiety disorder because of the presence of persistent anxiety, hypervigilance, exaggerated startle response, and phobic-like avoidance behaviors (Meichenbaum, 1994). Arguably, while often studied in war veteran populations, this disorder is not limited to veterans but can be *in situ* in the battlespace.

The Warfighter, the HMD and Cognition

An argument that the current trend in the military to use advanced technology to reduce manpower requirements and to overcome the vast physical demands of military training and combat has been presented. This argument has further stated that today's military environment is information intensive, and that this information is increasingly being presented in a head-up approach using head- and helmet-mounted displays. This deluge of information places a tremendous cognitive workload on the Warfighter. It is imperative, that, if HMDs are to indeed become a functional and useful technology, their design and execution be accomplished through a comprehensive understanding of their sensory, perceptual, and cognitive implications. Without a doubt, modern Warfighters, whether on land, under the oceans, in the air, or in space, are a special group who operate in environments unforgiving of human error, where cognitive degradation or failure can lead to, at best, an incomplete mission and, at worst, catastrophic consequences (Westerman et al., 2001).

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